IV. ADVANCED SNOWPLOW RESEARCH IN ARIZONA

Highway travel in winter storm conditions is hazardous to all drivers, who face a combination of obscured visibility, blowing and drifting snow, high winds, slippery road surfaces, and erratic movements by other vehicles. The potential is significantly higher in these conditions for rear-end or sideswipe crashes, and in a storm, stalled or slow-moving vehicles are a further hazard.

In snowplowing operations, these specific dangers are much greater in the extreme low visibility of wind-blown snow and the "snow cloud" that the snowplow blade creates around the truck. Snow and ice that is thrown up by the plow blade builds up on the lights, windshield and mirrors, and the truck's standard windshield wipers, washers and defrosters generally are not adequate for this service. Vision ahead, and to the rear and sides, becomes extremely limited.

The overall result is that in a heavy snowstorm, visibility is worse for snowplow operators than for any other drivers, especially those in the high cabs of tractor-trailer rigs. At the same time, these conditions are most likely to obscure stalled cars, fallen rocks or trees, animals, or people in and along the roadway. Vehicles in motion are another constant concern, especially for a nose plow and wing plow combination that clears both the lane and right shoulder at once. A greater challenge in whiteout conditions is staying in the proper lane, and even staying on the roadway.

For these reasons, and with strong interest and sponsorship from ADOT's senior management, this research project was initiated in late 1997 with an early emphasis on snowplow operations. Over the four previous winters, two distinct phases of research into infrastructure-based snowplow guidance concepts were completed. Three previous reports have been published by the ATRC, which conducts this ADOT research program as an in-house effort.

This new report 473(4) describes Phase Three (Year Five) of the project, in which the research focus was shifted from roadway lane-guidance systems to commercial on-board driver warning technologies for winter maintenance.

PROJECT EVOLUTION

ADOT first became involved with Intelligent Vehicle (IV) research activity shortly after the National Automated Highway Systems Consortium (NAHSC) "Demo '97" exhibition in San Diego, California. This landmark IV showcase for vehicle control concepts and fully automated highway systems (AHS) was a turning point in perceptions for many senior managers of ADOT.

ADOT and ATRC organized "smart car" tests and demonstrations for state leaders and the media in late 1997 and 1998. These local AHS and IV concept "demos" emphasized the potential of ITS technologies to improve safety, reduce congestion, and improve air quality. While perhaps less photogenic than the hands-off driving and fully automated platooning of AHS technologies, new ITS concepts for heavy vehicle operations were also being showcased at this time.

The key Phoenix-area AHS demonstrations included several prototype passenger cars employing both machine-vision and roadway-based guidance systems. The latter category included both the magnetic tape Lane Awareness System (LAS) developed by the 3M Company (3M) and the fully automated roadway magnet concept of the PATH (Partners for Advanced Transit and Highways) technology consortium between Caltrans and the California state university system. The PATH system was demonstrated on a closed course at Arizona State University in Tempe.

Despite the success of the Arizona demonstrations, ADOT soon realized that the infrastructure costs for AHS technology in the urban areas could not be balanced by congestion or air quality savings, nor was there any sign of near-term AHS initiatives by the major vehicle manufacturers.

Figure 4: Demonstration of Caltrans-PATH Concepts: Tempe, Arizona (1997)

In the post-Demo '97 time period, the national research emphasis gradually shifted to practical gains in safety and efficiency, an approach that pointed towards specialty vehicles. The transit, public safety and roadway maintenance fleets would become the primary focus of IV research and development. Around the country at this time, several research programs were being initiated that focused on snowplow driver-support systems in particular. ADOT and the ATRC also clearly recognized this need, and the program direction for this advanced vehicles research project began to crystallize.

Prior Phase One Research in 1997-2000

ADOT's Phase One research project, from 1997 to 2000, began with the "Arizona AHS Demos" in the Phoenix area, and with outreach to other key state agencies that were involved in vehicle research. The key project goals were to improve safety for both travelers and ADOT personnel, to defer more highway lane construction by maximizing the capacity of current roadways, and to improve regional air quality in Arizona.

While the original Phase One concept was to explore potential solutions for both urban and rural highway congestion problems, ADOT's senior management soon determined that the best near-term potential use of these new technologies was to improve the safety and efficiency of winter storm maintenance operations. Zero visibility conditions in snowstorms, together with heavy traffic on key route corridors, were issues that convinced ADOT to focus its research on evolving

ITS concepts that could significantly improve safety and efficiency for the snowplow operators and, as a result, for the traveling public.

Based on Demo '97 contacts, ADOT soon initiated a partnership with Caltrans, the California Department of Transportation, to field-test their prototype Advanced Snowplow (ASP) in Arizona. The Caltrans ASP utilized the PATH roadway magnets with specific coding to inform the snowplow of its position in the lane, and to predict the roadway curvature ahead. The ASP also employed an integrated collision warning radar system (CWS) prototype.

Figure 5: Caltrans RoadView ASP on US 180 in Arizona

The ATRC research project developed a six-mile test loop on US 180 at Kendrick Park near Flagstaff. This site allowed Caltrans to expand and diversify the research experience in different weather and terrain conditions, with a pool of Arizona snowplow operators. The California-PATH guidance system, installed on a 10-wheel Caltrans snowplow truck, was successfully tested in Arizona during the winters of 1998–99 (ASP-I) and 1999-2000 (ASP-II).

By the second winter season, however, the project sponsors realized that ADOT needed to obtain its own driver-assistance systems to effectively conduct full-winter, long-term testing. The ASP was an operational Caltrans snowplow, so the ADOT field-test period was limited to just four weeks, and technical issues further reduced the time it actually spent on the highway. These limitations led ADOT to expand its research into a new Phase Two, seeking to develop more hands-on experience than the Caltrans snowplow guidance partnership could provide.

This initial broadly-scoped research project, including the Arizona "smart-car demos" and the extensive partnering effort with Caltrans to establish an ASP test site on US 180 near Flagstaff, is described in detail in ATRC Final Report No. 473(1), *The Arizona Intelligent Vehicle Research Program – Phase One: 1997-2000.* [1]

Prior Phase Two Research in 2000-01

The Phase One research partnership with Caltrans was successful, but the results were clearly limited by the prototype status of the advanced snowplow system, and by the vagaries of winter weather. Just one month each winter with the Caltrans ASP in Arizona allowed for only limited testing, with limited results. For Phase Two, the third year of the project, the project's TAC mandated a new research effort to equip an ADOT snowplow with a roadway-magnet-based guidance system, to allow long-term concept evaluations in Arizona.

Figure 6: Arizona's Advanced Snowplow System: The ADOT-3M ASP

At this time, the Caltrans program did not have the staff resources to support a second ASP system outside of California. Also, the new RoadView[TM] snowplow, which superseded the earlier Caltrans ASP-II vehicle for 2000-01, was the sole developmental prototype. Many key RoadView components were not packaged systems, but were unique or even hand-built. ADOT therefore decided to procure a 3M Lane Awareness System (LAS), as well as five miles of 3M's magnetic striping tape. The tape was installed in mid-2000 at a site near Sunset Crater northeast of Flagstaff, between the layers of new pavement in a roadway reconstruction project on US 89.

The new Arizona research vehicle was designated as the ADOT-3M Advanced Snowplow (ASP). It was commissioned with the complete 3M Lane Awareness System (LAS), including a display screen, warning lights, and vibratory warnings. By placing the magnetic tape on the roadway centerline between the two traffic lanes, the per-lane cost of embedded infrastructure for the LAS was cut by half. The new ADOT-3M ASP was also equipped with standalone collision warning radar, and with an automatic vehicle location (AVL) system.

A new factor in ADOT's Phase Two research program was the need for a formal, unbiased analysis of the Arizona training and evaluation results for the 3M and Caltrans driver-assistance concepts. Flagstaff's Northern Arizona University (NAU) was assigned to monitor the training

and testing, to develop third-party evaluation results, and to make recommendations for possible future implementation. The 3M Company also augmented the ATRC's evaluation effort with a parallel Arizona evaluation program that was conducted by the University of Iowa (U of I).

ADOT continued its long-term project commitment to Caltrans in Phase Two, with a new goal to compare both guidance systems operationally in similar weather and road conditions. However, Phase Two was not a complete success, primarily for technical reasons. Both ASP snowplows had various guidance and warning system issues that resulted in extensive diagnostic downtime. Additionally, the embedded tape at the 3M test site was not usable due to alignment problems with temporary lane striping that was placed on US 89 for the winter construction shutdown.

This project's second phase encountered a number of setbacks in the winter of 2000-01, as noted above, but the equipment tests and the driver training program for both systems proceeded as planned at the two regional test sites near Flagstaff. The ADOT-3M snowplow was able to conduct non-ASP field operations at intervals through the winter season, and the Caltrans ASP did conduct plowing operations to a lesser extent during its brief month in Arizona. The system failures were a significant disappointment because the Flagstaff area received 125 inches of snow through the winter, which would be the highest seasonal snowfall figure for the entire project.

Despite the setbacks, the Year Three effort was productive, as detailed in the ATRC's Final Report No. 473(2), *Arizona Intelligent Vehicle Research Program – Phase Two: 2000-2001*.[2] The key accomplishment was that Arizona had established the first advanced snowplow test program in the West with dedicated real-world high-altitude test sites for both the Caltrans and the 3M systems, only 30 miles apart.

Prior Phase Two(b) Research in 2001-02

Phase Two(b) of Arizona's Intelligent Vehicle research program continued and evolved from the two earlier efforts. This was the fourth winter (2001-02) of ATRC's long-term research program to evaluate and compare state-of-the-art advanced snowplow systems in Arizona.

With Phase Two(b), the ADOT snowplow research project finally achieved a higher level of success. Guidance system evaluations were conducted with side-by-side field testing of the ADOT-3M magnetic tape and the Caltrans-PATH roadway magnet concepts. The same-day training program, field testing, and operator evaluations of the two low-visibility, low-speed guidance systems were quite successful.

Both the Caltrans RoadView and the ADOT-3M snowplows proved to be reliable and effective in their respective training, evaluation and operational phases. However, the Year Four (2001-02) winter brought less than half of the "normal" snowfall (39 inches) to northern Arizona. Worse yet, no snow at all fell in February during the fourth and last annual visit of the Caltrans RoadView snowplow to the Flagstaff test site.

At this point, the project's Technical Advisory Committee recognized that the economics of the infrastructure systems would continue to severely limit those applications in Arizona, and the project team began to steer the research toward new on-board concepts.

The fourth winter of the research project is described in the ATRC's Final Report No. 473(3), *Arizona Intelligent Vehicle Research Program – Phase Two(b): 2001-2002*.[3] This third report

reviews the Year Four results, discusses the decision to change the basic ASP research concept, and introduces the ATRC's buildup for the crucial fifth and final year of the project.

CURRENT PHASE THREE RESEARCH: 2002-03

This new Phase Three project report describes the recently concluded final winter season of the Arizona Intelligent Vehicle research program, which continued and evolved from ATRC's previous efforts. Phase Three was the fifth winter (2002-03) of ADOT's long-term in-house research effort to evaluate and compare state-of-the-art driver-assistance systems for snowplow operations in Arizona. Phase Three of this research has evolved to on-board systems, focusing its efforts on deploying both collision warning radar and passive-infrared night vision systems.

The Arizona evaluation workplan for the current Phase Three evolved from the ATRC's long-term partnership with the Caltrans test program in California. However, with no infrastructure elements involved, the research plan would no longer conduct centralized orientations and driver training, nor was a third-party evaluator required. Over the previous four winters, report and survey formats had been developed and standardized as much as possible between the two ASP concepts. The ATRC plan for 2002-03 was to simplify and streamline the reporting process to reduce the drivers' paperwork burden, and then to follow up on the field operational results with periodic surveys and interviews.

The early chapters of this report provide background information on the earlier concepts and phases of the project, and on the transition to on-board warning system testing. From there, the report describes the concepts and the components for each of the commercial driver warning systems. It also describes the ADOT research plan, and discusses the results and conclusions for these two off-the-shelf, low-visibility guidance technologies.

The remaining chapters of the report review ATRC's Phase Three goals, challenges and results of the 2002-03 winter in Arizona, followed by the overall vehicle research program results and conclusions, and finally, the project team's recommendations for further advanced snowplow system implementation.